Ground Water Depletion from Residential Development in A Tertiary Aquifer, Emerald Ridge Subdivision, Southern Lewis & Clark County

Lewis & Clark Water Quality Protection District
James Swierc, P.G. October 2014

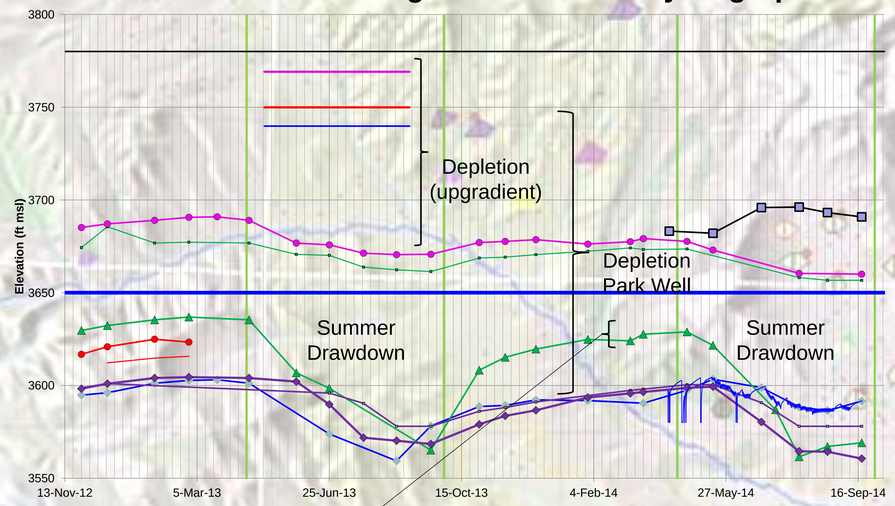
ABSTRACT

The Helena Valley aquifer represents the primary water source in the area, with natural recharge supplemented by irrigation waters obtained from the Missouri River outside of the local watershed. The valley-fill aquifer comprises high permeability unconsolidated sediment lenses of varying thickness, separated by lenses of finer grained material with lower permeability. Sedimentary geologists classify the aquifer material as Quaternary alluvium covering older Tertiary sand and gravel deposits with no distinct contact between the two different aged deposits. Based on this informal description, wells installed into Tertiary deposits are generally considered as completed within the Helena Valley aquifer.

The Emerald Ridge subdivision, located along the northeast margin of the Helena Valley represents a "typical" subdivision for the area. The subdivision is located on Tertiary strata on a bench adjacent to the eastern border of the Helena Valley. The original subdivision development plan, prepared in 2004, included 67 residential lots with water obtained from private wells. The source aquifer was identified as a sand and gravel deposit, with a water table at less than 100 feet. Recommended well depths were between 250 and 300 feet below ground surface. In response to the reports of well yield problems, the Lewis & Clark Water Quality Protection District (LCWQPD) initiated a study to document the hydrologic conditions in 2012, with a monthly water level collection program and limited water quality sampling. Due to water supply problems, by the end of 2013, only 50 lots had been developed with 28 of the lots having installed at least one replacement well. Replacement wells were installed to increasingly greater depths, with the most recent wells installed to depths exceeding 700 feet.

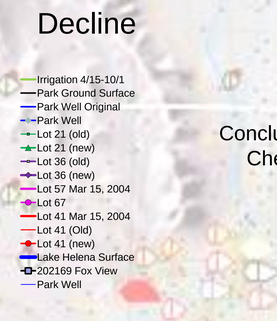
Data from the LCWQPD program indicate that the water table surface has decreased by approximately 100 feet along the western part of the subdivision, and 150 feet along the eastern side. Water levels have decreased to levels beneath the ground water surface in the adjacent Helena Valley aquifer, resulting in an eastward flow gradient between the two areas. Unfortunately, recharge does not appear to occur across the Helena Valley fault located between the valley-fill aquifer and the bench. The water quality type determined by major ion water chemistry shows that Emerald Ridge waters (Sodium-Potassium/ Bicarbonate-Sulfate type) are distinctly different from Helena Valley aquifer waters (Calcium-Magnesium/Bicarbonate type). The ground water temperature is approximately 5°C warmer than should be expected under a normal geothermal gradient. The thermal overprint suggests recharge occurs from vertical flow upward from depth. Oxygen and Deuterium isotope data for ground water support the interpretation of different water types and recharge sources. The study results show that the basin fault boundary represents a barrier to ground water flow, and that Tertiary strata have distinctly different hydrogeologic properties than both the Helena Valley aquifer and adjacent bedrock aquifers. This project demonstrates the importance of collecting data to characterize low yield aquifers for use to support local government planning efforts.

Emerald Ridge - Water Level Hydrograph

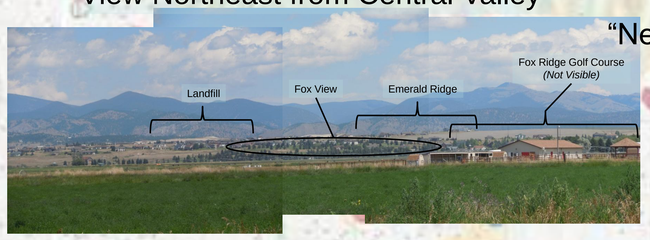


Ground Water Depletion

- Pumping Exceeds Recharge
- Water Levels Decline



View Northeast from Central Valley

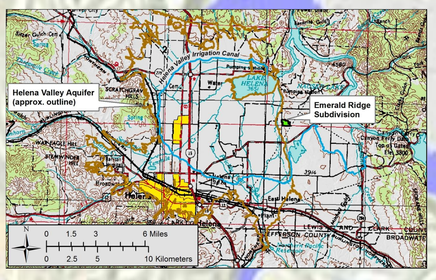


Subdivision Developed in 2004
67 Total Lots (16 Still Vacant)
28 Lots with Multiple Wells
Additional New Wells Needed
3 vacant, new homes

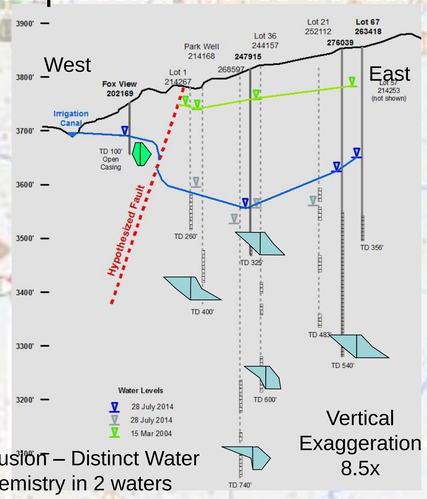
Original Wells in 2004 - <200' – 300' TD
New Wells in 2014 - 600' - >700' TD

"New Home Sites Available"

Location



Major Ion Water Chemistry Depletion in Cross Section



Vertical Exaggeration 8.5x

Conclusion – Distinct Water Chemistry in 2 waters

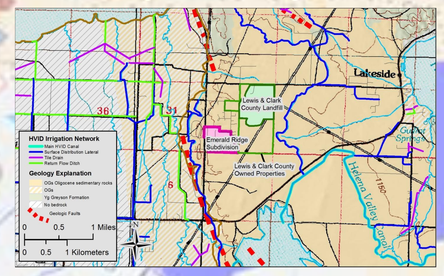
Stiff Diagram Explanation

Sodium (Na^+) + Potassium (K^+)
Calcium (Ca^{+2})
Magnesium (Mg^{+2})

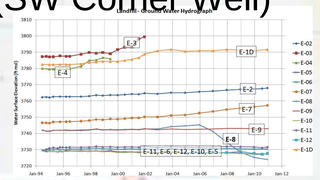
Chloride (Cl^-)
Bicarbonate (HCO_3^-)
Sulfate (SO_4^{-2})

5 0 5
Milliequivalent per liter

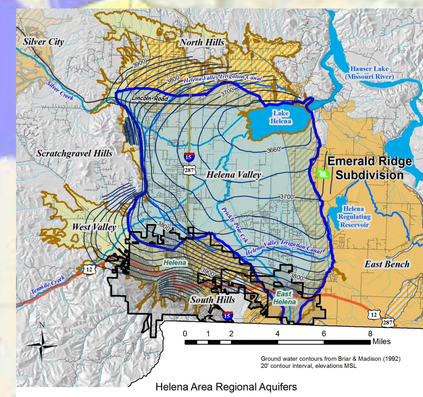
Geologic Setting



Drawdown at Landfill (SW Corner Well)



Helena Area Aquifers



Helena Area Regional Aquifers

1. Outline of coarse soils from US Natural Resource Conservation Service. Where present, these are on top of underlying Tertiary or bedrock. Helena Valley Alluvial Aquifer outlined in central part of this area. The alluvial aquifer is present where ground water is obtained in unconsolidated deposits. Ground water is shallow in central valley. Aquifer has high permeability and yields. Outside of the aquifer area, ground water is generally obtained through Tertiary or bedrock aquifers beneath coarse soils.
2. The Tertiary geologic deposits are present in the eastern part of the planning area,
   Areas where Tertiary deposits are present with little to no soil cover. Ground water resources vary widely.
   Tertiary aquifer in subsurface, where wells may be installed into Tertiary deposits through overlying materials.
3. All other areas have bedrock near surface, with thin soil profile. Exceptions may be present in mountainous areas, where localized valley fill deposits may provide local, high yielding aquifers.

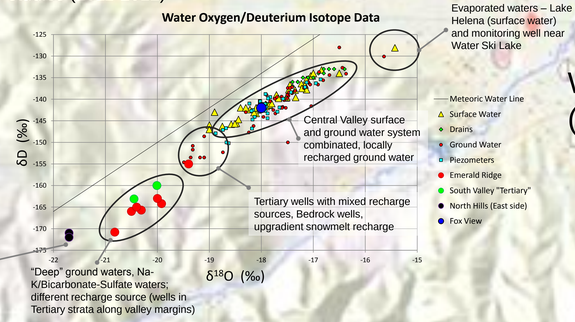
Note: The primary data sources for the map include Briar & Madison (1992), Thamke (2000), NRCS Soils, and local MBMG studies (2012, 2013). Boundaries in the subsurface are estimated from listed sources, and reflect current estimates of locations. Unit boundaries are valid at a valley-scale, and can't be used for site-specific assessments where site data is required.

Isotope Hydrogeology

Oxygen and Hydrogen Isotopes of Water
Datasets: MBMG-GWIP Studies (2010)
LCWQPD Non Point Source studies (2011-2012)

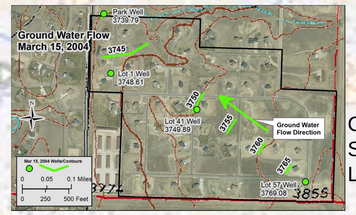
Water isotope data:
surface water samples,
piezometer samples
ground water well samples.
(Piezometers are shallow wells adjacent to streams)

Water isotopes represent conservative tracers from recharge area through system

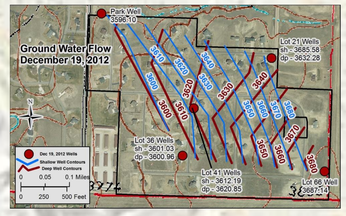


Conclusion – Distinct Water Type Difference from Area Waters

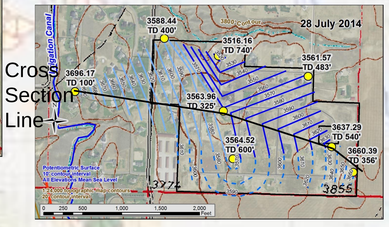
Original Water Table Surface (2004)



Water Table Surface (19 Dec 2012)

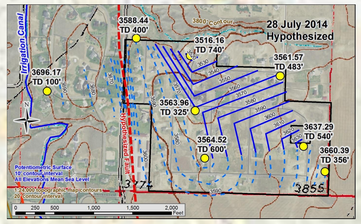


Water Table Surface (28 July 2014)

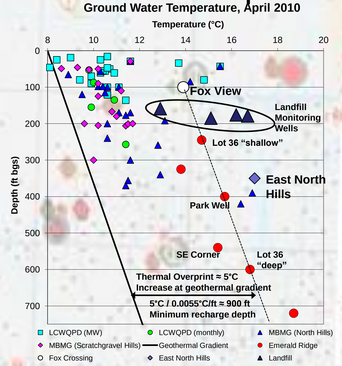


Cross Section Line

28 July 2014; with Hypothetical Fault seal



Ground Water Temperature



Conclusion – Different thermal regime from Helena Valley

Conclusion – Ground Water Flow Direction has Changed

Ground Water recharge from Helena Valley Not Occurring – Fault Hypothesized as seal to water flow/recharge

Conclusions:

- Depletion Occuring from over-pumping wells
- Tertiary Strata separated hydrologically from Helena Valley Aquifer
- Data Evidence:
  - Ground Water Flow
  - Ground Water Temperature
  - Ground Water Quality Type
  - Ground Water Isotopes

All show differences

Note – data from East Side of North Hills shows similar properties,